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A key ingredient in the analysis, planning, implementation and operation of any successful transportation system requires accurate and realistic forecasts of traffic volume expected to use the system. Although the planning process involves much more than a forecast of the future traffic statistics, these statistics provide an essential quantitative dimension for the planning process. Forecasts of expected traffic are therefore an essential prerequisite to both long and short-range planning.

This paper outlines the basic techniques of forecasting the air passenger traffic. The differences between the various forecasting methods exist, in part, due to the degree of formalization of the forecasting procedure. Each technique has its special use and the selection of an appropriate technique depends on a number of factors such as particular application, available data, projection period and desired accuracy.

Forecasts can be classified according to the time period they cover. "Short-term" forecasts are normally used for planning current policy, evaluating current developments, and in general are concerned with the day-to-day operations. The time framework can range from one month to a year. "Budget" forecasts normally refer to a fiscal year and are used for establishing basic operating requirements such as determining cashflow and adjusting station employee requirements in line with seasonal movements in traffic.

"Long-term" forecasts normally cover a period of three to fifteen years. They are generally used for fleet planning, market and route planning, etc. Time frame for the forecast will influence the selection of the technique. For example, a long-range forecast of the market potential of a given route requires a different forecasting technique than a forecast of the system traffic for producing next year's financial budget.

One of the most crucial trade-offs in the selection of a forecasting technique is of accuracy versus cost. Although greater accuracy can be obtained at higher costs, there is usually an optimal point beyond which diminishing returns take over. In this context, the cost of the forecast is used in the general sense. It includes such components as time required to forecast, use of computer facilities, the additional cost of acquiring more suitable data, the cost of error in the forecast, etc.

Techniques for forecasting air passenger traffic can be broadly classified into four categories: judgmental, time-series analysis, market analysis and analytical. The judgmental or subjective method relies on the analyst to make an educated guess of the travel demand for the forecast period based on his experience of the past volume of traffic and his intuition of the future.

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Although the analyst does not use any specific travel demand model, he intuitively takes into account the factors which influence the demand for air travel and weighs these factors according to his judgment. This method is especially useful in cases where the data sample is small or nonexistent as may be the case requiring traffic forecast on a new market or a forecast of the market acceptance of a new type of aircraft. Although the judgmental method has the advantage of low cost and ease of operation, it is limited to short-term forecasting. This approach has little merit in long-term forecasting since it is natural, although perhaps, unintentional, for the analyst to place greater weight to more recent developments.

The judgmental forecast can be produced by a single analyst or by a committee as with the delphi technique. In the delphi method, a group of experts is consulted through a set of carefully designed sequential questionnaires. The answers to one set of questionnaires are used to design the next set and all members in the group have access to each other's information.

The time-series analysis method assumes that the air passenger traffic will follow its established pattern of growth. This means that the future travel demand is a time function of the past experience. The time-series analysis, therefore, assumes very little causation. The method can be useful for broad long-term projections especially in cases where there is very little knowledge on the cause for growth. On the other hand, the method has little merit for

forecasting detailed long-term patterns. Since the assumption of the future being direct function of the past is more likely to be true in the case of short-term, the trend method can be very useful for producing detailed forecasts on the short-term basis.

The application of time-series analysis varies from the simple extrapolation of historical trends to the use of complex mathematical growth curves, such as the Logistic and Gompertz curves. These are known as intrinsic models, that is, time is taken to be the only predictor variable, reflecting the interplay of economic, industry, and government activities. The difficulty lies in determining accurately the appropriate trend curve. We can use empirical and theoretical considerations to narrow the selection of the growth curve. For example, the very long-term forecast of the air passenger traffic in the United States may be estimated by an asymptotic trend, such as a Gompertz curve, since there are good reasons to place an upper limit on the level of traffic.

The simple extrapolation involves a projection of past observed trend through visual inspection. Although such a method will suffice for certain applications, direct extrapolation, in general, is not considered a satisfactory method of forecasting especially for cases involving turning points. The method merely indicates that parameters exist which have influenced the demand in the past at a rate which is a function of time. It is, therefore, difficult to project the

demand based on time alone unless one knows these time-based parameters and the extent of their influence. It is also difficult to forecast the time at which these influences may cease to operate or their effects will change. For example, it is well-known that the sea traffic on the North Atlantic has been declining steadily. A direct mechanical extrapolation of this trend will produce a total disappearance of the sea traffic on this route after a certain time. A reasonable forecast, on the other hand, would set a minimum on the passenger market patronizing the water mode.

For annual budget forecast, the analyst is usually interested in forecasting monthly traffic which can fluctuate due to trend, cyclical and seasonal factors. In addition, the seasonal traffic pattern may contain random noises. The long-term trend is usually the result of steady and continuous increases in population and technical improvement. The cyclical fluctuations are generally the result of movements in the economy or business cycles and do not usually conform to a set pattern. The seasonal effects occur at a given time in the year and are usually the result of season or custom. The random noise is the irregular or the residual part of the pattern. The time-series forecasting model attempts to project the value of the first three components of the series and sum the results to get the forecast value of the traffic. It is usually impossible to forecast the random noise component.

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Various time-series statistical models are available to analyze and forecast values of a fluctuating pattern. Smoothing techniques are the most common means of investigating time-series components. These techniques attempt to cancel out the random effects by using "averages." The normal smoothing schemes are the moving average type and the exponential smoothing. The former scheme calculates averages over a fixed base time period while the latter scheme calculates an average using all past values of the series. The weight given to the individual value of the series is determined by the smoothing constant.

The accuracy of this method depends on the behavior of the traffic pattern. A well behaved pattern with small random variation will be relatively easy to forecast compared to one containing a significant random pattern. Normally the historical raw time-series data is adjusted and massaged to eliminate known distortions caused by ad hoc factors such as strikes, introduction of new aircraft, bad weather and extra ordinary large scale promotion. A forecast of the time-series model can then be used on the clean data to produce a forecast of the seasonal traffic pattern. The experienced analyst would then apply to the predetermined forecast intuitive factors such as expected changes in competitor's traffic, introduction of excursion fares, and movements in economy to obtain a more realistic traffic forecast for budget purposes.

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The market analysis method relates the travel patterns of a given segment of the population to its demographic and economic characteristics. The Port Authority of New York and New Jersey has investigated the use of this method based on a series of national household surveys conducted over a period of fifteen years. The results of these surveys indicate a strong relationship between the travel pattern of a group of people and such characteristics as income and occupation. A forecast of the air traffic activity is obtained from a forecast of the demographic and economic characteristics of each of the population segments.

The air travel market is usually divided into a large number of "cells" each defined by a cross-classification of socio-economic characteristics such as age, education, occupation, and income for personal travel and industry, occupation and income for business travel. Once the cells have been established, a relationship is investigated between air trips and these characteristics. This relationship is then applied to a forecast of the segment of population expected to fall under similar cells to obtain the projected number of air passengers for all cells. Projections of population and its distribution with respect to age, labor force, income groups, etc., can usually be obtained through sources such as United States Census Bureau and United States Department of Labor.

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There are three critical assumptions regarding the validity of this method. First, an assumption has to be made regarding the stability of the relationship between travel patterns and the socio-economic characteristics. Secondly, a realistic assumption is needed on the projected growth of the traffic group within an individual cell. Third, the model should take into account future expected changes in the socio-economic structure of the population and segments of the population which are not included in the surveys.

Market analysis can be an extremely useful tool in identifying those segments of the population which generated most of the air activity and those which are good future potentials. The weakness of the method is that it does not take into account service characteristics such as fare and trip time. The market analysis method, for example, will not be able to relate the changes in the demand for air travel to changes in the average fare level or introduction of new fares introduced to attract a certain market.

The market surveys can be taken from actual travelers or from households with potential travelers. In the later case, consumers are asked about their travel intentions and the responses are subject to many "errors". The most common of these is due to misin-



terpretation and lack of ability to quantify subjective responses. The common limitations of these surveys are that the respondent may not be the ultimate decision-maker or that he may be unable to state accurately his travel plans. In any case the plans can change due to family circumstances and general economic conditions.

The analytical method attempts to relate the variation in the movement of logically relevant economic variables such as income, demographic variables such as population, and service variables such as fare and trip time. This method explores and analyzes parameters which have affected the historical travel demand pattern and those parameters which may influence the future travel demand. An analytical demand model shows through one or more equations, an economic relationship between demand and a number of predictor variables which can be classified as exogeneous or endogenous. The endogenous variables are determined within the model itself while the exogenous variables are predetermined. It should be noted that although time can enter the relationship as a predictor variable, it cannot be the sole predictor variable. It must also be emphasized, however, that statistical correlation does not always imply cause and effect. In many cases the relationship is empirical or logical at best.

There are basically four steps in building an analytical model: specification, data analysis and collection, calibration, and evaluation. The specification stage involves the formulation of a set of testable hypotheses showing the relationship of volume of air passenger traffic with economic and transport-related variables. It refers to the task of formulating a set of precise mathematical equations. The selection of the variables is based on the considerations of empirical data, economic theory, statistical techniques and computational advantages. Since the relationship cannot be an identity, it is usual to include an error or residual term.

The next step involves the analysis and collection of past data on both the dependent and the independent variables. This is a very critical step since the unavailability of certain types of data can force the analyst to an alternate model specification. The data analysis is usually performed with respect to sample size, reliability, consistency and availability of projected values. The data collection involves not only the gathering of statistics but the adjustment of the data for ad hoc influences such as strikes.

In the third stage of the model development, the parameters of the regression equation are estimated from the past data on both kinds of variables. The calibration of the model is carried out by deriving the appropriate functional relationship through experimentation with the past data and the use of regression techniques.

For a base period, various functional relationships are empirically manipulated. The object is to find the relationship which gives the least variance between the derived demand and the actual demand.

The final step is an evaluation of the model in terms of its effectiveness to explain the volume of traffic. This step may lead to an alternative specification of the model and hence, repetition of the first three steps. In general, model evaluation can be performed in two steps. First, it is necessary to justify the model on theoretical grounds. For example, a travel demand model with positive price elasticity should be questioned on logical ground. The second stage of evaluation is based on statistical validity. The four most common indicators of statistical validity are degrees of freedom, the coefficient of determination, standard error of the regression coefficient, and the standard error of estimates. For greater details on the significance of these tests, a standard text on econometrics can be consulted.

There are three fundamental assumptions underlying the analytical approach. First, it is assumed that most of the variation in the dependent variable can be explained by using a few selected independent variables. This assumption is necessary due to the availability of limited data. Furthermore, in many cases it is difficult if not impossible to quantify all the variables even though we recognize that these variables have influenced the volume of traffic in the past and will continue to do so in the future.

The second assumption is that it is easier and/or more accurate to forecast the independent variables than the dependent variable. Normally the data for the projected values of the independent variables can be obtained directly from external sources, giving the analyst two advantages. First of all, certain external specialists in various branches of the government, private industry, and/or academic institutions are probably better equipped to produce the projections. Secondly, it is important that the assumptions regarding the projections of economic activity should be consistent. The third assumption is that the functional relationship will remain valid throughout the period for which the forecast is required.

Like any other method, the use of analytic technique has its own problems. Again without going into depth, the two most common problems associated with this method are multicollinearity and autocorrelation. The former is caused by the existence of relationships among some of the independent variables. The term autocorrelation is normally used to describe the lag correlation of a particular time-series with itself. This problem can cause the model to systematically "overshoot" or "undershoot" the pattern.

In the past, most forecasts have relied heavily on the use of time-series analysis. In cases where attempts were made to formulate

more sophisticated demand models, the scope was limited due to unavailability of statistical data such as volume of traffic by purpose of trip, discretionary personal income and lack of the ability to measure certain factors, such as taste and the effect of advertising. Current research is devoted to developing models which are analytic, multivariate, behavioral, dynamic and probabilistic.

The analytic formulation offers the advantage of statistical tests of several groups of alternative hypotheses relevant to the demand for air travel. The multivariate characteristic allows the model to contain more than one independent variable. The behavioral model of demand relates the consumer behavior to observable decision-making processes. This approach focuses on rational consumer behavior under insufficient knowledge. The dynamic nature of the model will eliminate the assumption that the demand coefficients, for example, income and price elasticity, should remain constant over time. In the real-world and on "a priori" grounds, it is expected that the long-run partial coefficients of the explanatory variables in the market demand function will vary with time. The probabilistic characteristic allows the analyst to treat the demand for air travel as a random variable and obtain an approximation for its probability distribution together with an estimate of the expected value and

variance. This method is particularly useful when the demand is a random process due to lack of data or insufficient knowledge about the variables which affect air travel.

The model can be expressed as a system of simultaneous equations, thereby lifting the constraint that all of the explanatory variables will be exogenous with virtually zero feedback. For example, there is a feedback relationship between the type of aircraft available and demand. The demand for air travel should be denoted as an explicit function of a small number of systematic variables which are presumably more important and can be quantified fairly easily. The net effect of the secondary variables can be represented by a stochastic variable. This variable can account for all forces which should be included explicitly in the behavioral demand model but are either unquantifiable or subjective. On theoretical grounds, some of the predictor variables may assume a lead-lag structure. The model can also incorporate dummy variables which will relay, for example, the existence or non-existence of SST, sonic boom, etc. In the final analysis, the sophistication and complexity of the model will depend largely on the availability and the degree of quantification of the data.

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